The Spanish Research and Development System: a model for the equilibrium conditions between the offer and the demand of new researchers

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ABSTRACT

The System Dynamics model which we are presenting here has been prepared with the purpose of examining the relations between the number of existing grant-holders in Spain and the number of researchers in active service in the sectors of Higher Education, Business and Public Research Organisms. The aim is to examine these variables in order to analyse the conditions of balance between the offer of potnential researchers trained while holding grants and the demand for new researchers on the part of the science and technology system in Spain.

1. INTRODUCTION

In this paper we present the most relevant conclusions from the system dynamics model that we have built up in order to study the future needs of new researchers in Spanish Research and Development system. This SD model is an outcome of the EPOC project (Quintanilla et al. (1992)), a general study of the Spanish science and technology system and its recent evolution, carried out during 1991 in the University of Salamanca, and finnanced by the Spanish Government. In the "Science and Technology" system we include the set of activities and institutions with social relevance for the scientific research and for the technological development (Quintanilla (1988)). This definition of the scope excludes other agents and factors of our analysis, like the cultural and estrictly economics ones.

One of the areas in wich public planning is possible and necessary is the training of new researchers. To study the medium-term future needs of new researchers, we found that

the system dinamics methodology provides the proper frame, since it is necessary to model the behaviour of a system with a great number of interdependencies. For the Spanish case, we have considered separately the recent past evolution of three types of institutions: Business, Higher Education and Public Research organisms. These three subsystems have been integrated to determine the behaviour of the whole system, which imposes its own limits on the three.

2. THE SPANISH SCIENCE AND TECHNOLOGY SYSTEM

The two main objectives of the EPOC report were (a) to undertake an analysis of the Science and Technology System in Spain and its recent evolution and (b) to evaluate the incidence of the R&D policy of the Spaish government on the structure and evolution of the Science and Technology System.

The self-imposed limits of the EPOC report derived from these objectives. In the first place we were concerned ourselves strictly with the Science and Technology system. Naturally, a country's system of innovation does not only depend on scientific research. This limitation is coherent with the second aim of our study: the evaluation of the R&D policy of the Spanish government during the past three years. It is important to point out that we were referring to the policy carried out through the National Plan of Scientific and Technological Research, directed toward the promotion of national capacity in the field of scientific research and technological development. The scientific and technological policy of a country does not have to be limited to the promotion of research. Indeed, in the Spanish case there are other aspects of government policy which have a very direct influence on the development of science and technology. But we have focused our attention in the National Plan because it deals with a collection of political actions whose aims and instruments have been defined beforehand and about which sufficient basic information is available. On the other hand, we hope that our analysis of the first three years of operation of the National Plan (1988-1990) can contribute elements of good sense for its revision in the future.

In our study we have observed that the human resources of the Spanisch Science and Technology system, like financial resources, have grown during the last few years at a high rate (the highest of the EEC). In spite of this growth, Spain's effort in human resources dedicated to R&D
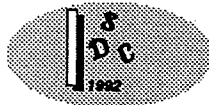
is still very low in comparison to the EEC countries; in 1988, the number of researchers in Spain represents aproximately 7% of the EEC total and signifies 2.1 per 1000 of the working population, against a community average of approximately 3.8. Nevertheless, the relation between financial effort and effort in human resources is coherent with the general level of development of the Spanish Science and technology system. Consequently, the measures which are adopted to cause the general growth of the System should attend to both factors, financial resources and human resources, with the same intensity.

The Spanish university is limited by the excesive weight which academic specialities of a humanistic or professional character have in it compared to technological ones, and to a lesser extent scientific ones. Although there are signs that this situation is evolving, the change is slow and, to strecgthen the training of researchers special, and to a certain extent vigorous, measures are required. These conclusion endorse the importance of the aims stablished by the National Plan: the training of researchers.

By researchers in training we mean those university graduates who are following up regular post-graduate courses and are preparing their doctoral theses at universities in Spain and abroad. Knowing the number of researchers in training and their distribution according to scientific specialities is important for us to be able to evaluate the growth potential of the Science and Technology system. Furthemore, given the importance that the grant system has at this level of education, the analysis of these data is also relevant for taking decisions with regard to the funds which should be earmarked for grants for the training of researchers,depending on the objectives of the anticipated growth rate, etc. We should consider the adaptation of the public effort in the training of researchers to the needs of the growth of the Spanish Science and Technology system. In order to analyze this question we have done a System Dynamics model.

3. THE RESEARCHERS/GRANT-HOLDERS MODEL

To prepare this model we have used System Dynamics and, for its implementation in a computer, we used the **Professional Dynamo**.

In the construction of our model we have guided ourselves by the following considerations:

(1)   The training of researchers in Spain is basically
        carried out through the awarding of grants to young
        people who have already obtained a degree and who
        are preparing for their doctorate or who merely wish
        to broaden their knowledge in Spain or abroad. The
        overwhelming majority of these grants are financed
        with public funds from the various administrations.
        An important part of these grants comes from the
        Interministerial   Commission   for   Science   and
        Technology or from the Ministry of Education and
        Science in accordance with the priorities of the
        National Plan.

(2)   Although not all the new researchers that become
        part of the science and technology system have
        previously been grant-holders, the grant system is
        the procedure that the Administration has at its
        disposal to promote the quality of the training of
        new researchers and to give direction to the offer
        of potential researchers in coherence with the top
        priority policies of the National Plan. Therefore,
        to start with, it would appear to be desirable to
        achieve a level of offer of former grant-holders
        that would be sufficient to cover a significative
        percentage of the needs of the incorporation of new
        researchers into the science and technology system.

(3)   Grant-holders require a certain degree of attention
        and dedication on the part of active researchers.
        Furthemore, the incorporation of new researchers
        into the system must be done at an appropiate pace
        in order to guarantee the efficient integration into
        research teams. Therefore, there are certain
        objective limits, both for the number of researchers
        being trained (active grant-holders) that the system
        can support, and for the number of new researchers
        that the system can incorporate.

    These considerations justify some of the hypotheses which
we have included in the model.

4. VARIABLES AND BASIC HYPOTHESES

    The level variables are the number of grant-holders and
the number of researchers according to performance sectors
(Higher Education, Business and OPI). The fundamental
hypothesis refer to the growth rate of these variables, and
to the percentage of new former grant-holder researchers
that are incorporated into the system.

Data on grant-holders and researchers for the years 1981-1991 have been introduced as exogenous variables, based on Spanish national statistics (INE (1988)). The model starts from 1981 and the various simulations go as far as the year 2020.

From 1991 onward, the model calculates the annual evolution of these variables, applying a variable growth rate which is obtained from the following formula:

$$dV_{t-t'} = KV_t (1-V_t/V_m)$$

where V is the variable, t-t´is the time interval of one year, V_m is the masimum value taht the variable V can reach and K is a constant that differs for each V variable.

The value of K has been calculated in such a way that the growth rate for 1990-1991 coincides with the average annual accumulated growth rate for the period 1981-1990. This rate is of 4.08% for the Higher Education sector, 12.14% for the Business sector and 10.57% for the Public Research Organisms. For grant-holders from the National Plan, the effective rate was calculated only with data from 1987-1990, and turned out to be 19.89%. For the total number of grant-holders from the period 1981-1990, the average annual growth rate was of 19.59%.

It was established a limit, V_m, for the increase in the number of researchers. It was at 108.000 researchers in full time equivalent, which means that for Spain (taking as constant the country´s population of 40 million inhabitants) there were 2.7 full time equivalent researchers per 1000 inhabitants, a figure which is equivalent to that of the West Germany in 1987, according to data from the OCDE (OCDE (1990)). In order to calculate the growth rate of the number of grant-holders, the limit was established at 25% of the total number of existing researchers each year. This means that each year there can be no more than one active grant-holder for every four active researchers. Furthermore, it is assumed that the average period of time than one actually has a grant is of 2.9 years.

Based on data thus obtained, the demand for new researchers is calculated, adding a percentage of the number of researchers from the previous year, in order to meet the number of researches which would be necessary to fill the natural vacancies produced each year. These leaving rates have been calculated by a secondary SD model that simulates the evolution of the age distribution of the population of

researchers in the Higher Education (from the data included in Consejo de Universidades (1991)). In the main model these data have been introduced as an exogenous variable. The percentage goes from a 0.7% in 1991 to a 2.08% in 2020. For the Business sector and Public Research Organisms, it has been introduced the average percentage of the University. This is a 1.6%.

In order to calculate the deficit or surplus of former grant-holders, we have done various simulations, varying the percentage of new former grant-holder researchers that are incorporated into each sector each year. In all cases we have assumed that this percentage is identical for the Higher Education sector and the Public Research Organisms. For the simulations with data on grant-holders from the National Plan we have assumed that the percentage corresponding to the business sector is equal to 3/5 of the percentage corresponding to either of the other two sectors. For the simulation with data on the total number of grant-holders, the relation is of 2/5. There are no reliable facts to justify these options, but there are reasons to believe: 1) that the percentage of former grant-holders among new researchers in business sector is inferior to that of the public or universitary sectors; 2) that in the case of the National Plan grant-holders this percentage must be somewhat higher than normal, if we keep in mind that the training of the National Plan grant-holders is strongly directed towards areas that are considered top priority for the productive system.

With these data we have done different simulations in order to show in what conditions situations of balance, deficit or surplus of former grant-holders are produced.

5. RESULTS OF THE SIMULATIONS

To begin, we will present the results of the simulations done with the original model. All of them share the same pattern of evolution in the number of researchers (graphics 1 and 2). The number of researchers in 1990 would double in the year 2003 and in the year 2050 it would reach 104000 full time equivalent researchers. The maximum anticipated for the model is 108000.

With data on the total number of grant-holders, we obtain the following significative results (graphic 3). Based on the hypothesis that 50% of the new researchers that are incorporated into the system are former grant-holders, and 20% in the case of business sector (To abreviate we will
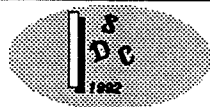
call this the 50-20 hypothesis), there doesn't exist a deficit of former grant holders after 1983. Based on the 40-32 hypothesis, there exists a deficit until 1993. Only on the hypothesis 100-100 there exists a constant deficit of former grant-holders, the maximum of which is reached in 1994. The deficit then continues to decrease until the year 2004 in which there is a surplus of 1169 former grant holders.

In conclusion, with the data from the model, we can assume that the grant system provides enough new researchers to progressively cover from 50 to 80% of the demand (from 20 to 32% in the case of business sector), aproximately up to the year 1993. If we think about the number of grant-holders that is necessary to cover the 100% of the number of new researchers, we see that we could reach it in the year 2004.

Lastly, we have done another group of simulations with the original model for National Plan grant-holders (graphic 4). In this case, based on the 100-100 hypothesis, a maximum deficit of former grant-holders is reached in the year 1999 and a superplus is reached only as of the year 2010. Based on the 80-48 hypothesis, there continues to be a deficit of former grant-holders until the year 2002. Finally, only with the 50-30 hypothesis is a continuous surplus of National Plan grnat-holders achieved from 1994 onward.

Consequently, according to our model, the growth rate of the number of National Plan grant-holders would make it possible to satisfy, from 1994 to 2002, between 50% and 80% of the demand for new researchers (between 30 and 48% in the case of business sector). From that point on, coverage of the demand could extend progressively until it reached 100% in the year 2010.

6. SUMMARY AND CONCLUSIONS

The EPOC model is a theoretical aproximation to the analysis of balance between the offer of former grant-holders and the demand for new researchers. We have extrapolated the data from the last ten years (1981-1991) and we have anticipated a growth rhythm lessened by to the proximity of a limit (following a logistic growth) that, in the case of researchers, is of 2.7 full-time equivalent researchers per 1000 inhabitants and, in the case of grant-holders, of one grant-holder for every four active researchers.

With these assumptions the model allows us to conclude

that the anticipated growth rate of grant-holders manages to cover nearly 80% of the present demand for researchers on the part of Higher Education and Public Research Organisms and 32% of the demand in business sector. This coverage rate will increase steadly until it reaches 100% in the year 2004.

As for National Plan grant-holders, we have assumed that the demand on the part of business sector will be somewhat greater. At present, these grant holders could cover less than the 30% of the demand in business sector and the 50% of the Higher Education and Public Research Organisms. With the growth rhythm anticipated for the model, in the year 2010 would reach the quota of 100%.
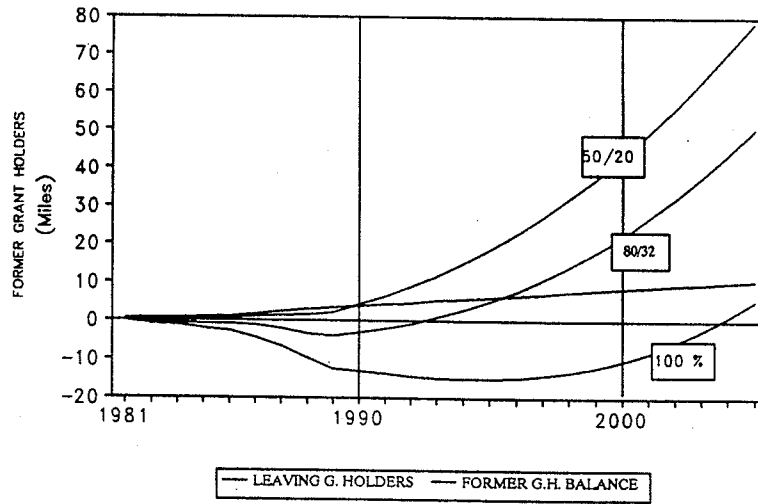
7. GRAPHICS

GRAPHIC 1. TOTAL RESEARCH SCIENTISTS
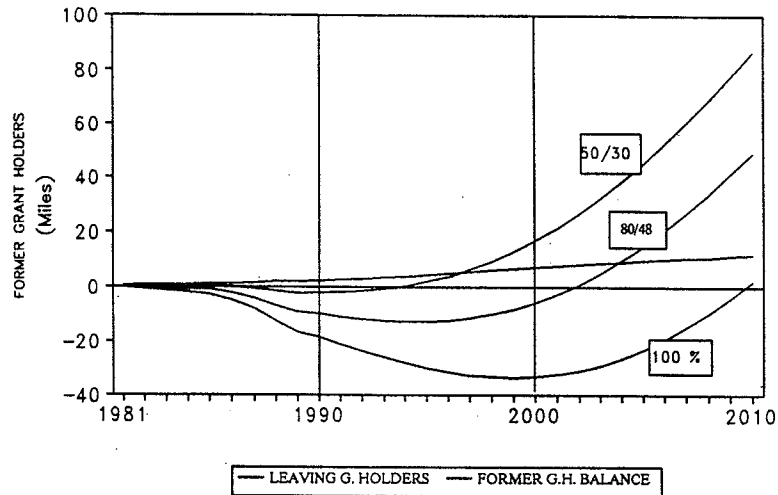AND ENGINEERS (RSE)
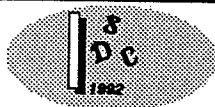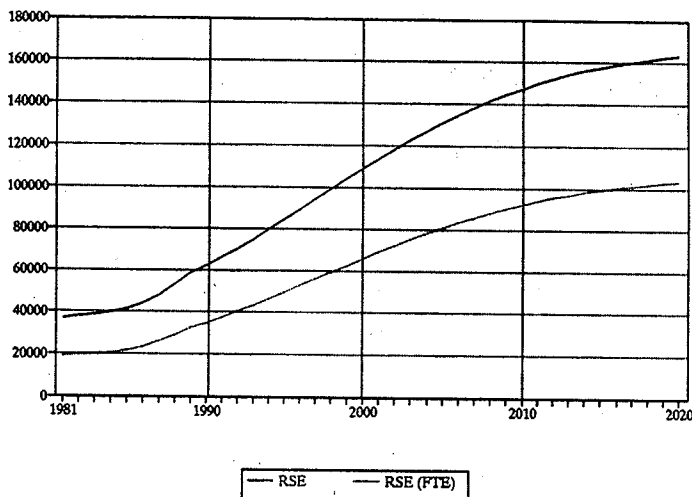
GRAPHIC 2. EVOLUTION OF RSE NUMBER
BY SECTORS

Legend: PUBLIC RES. ORG. — HIGHER EDUCATION ······ BUSINESS SECTOR
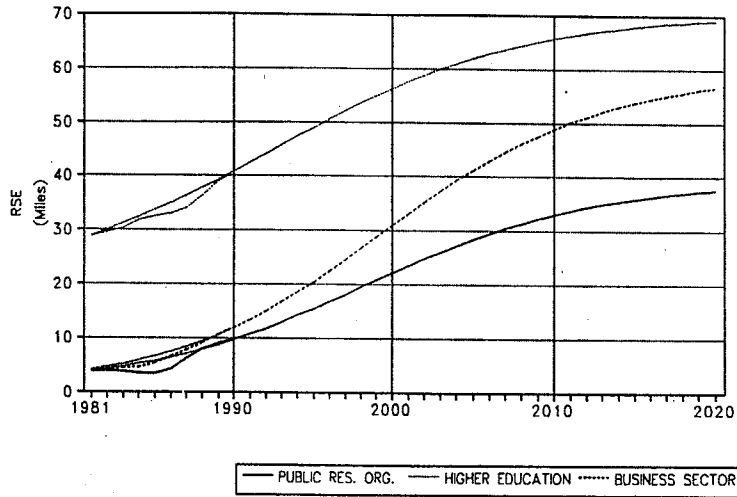
GRAPHICS 3. LEAVING GRANT HOLDERS AND
OFFER DEMAND BALANCE OF FORMER G. H.

Legend: LEAVING G. HOLDERS — FORMER G.H. BALANCE

GRAPHIC 4. NATIONAL PLAN LEAVING GRANT
HOLDERS AND OFFER DEMAND BALANCE

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